Approval Standard for Seismic Sway Braces for Automatic Sprinkler Systems

Class Number 1950

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Foreword

The FM Approvals certification mark is intended to verify that the products and services described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and

b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states Approval criteria for rigid seismic sway brace components and assemblies for automatic sprinkler systems.

1.1.2 Approval criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for seismic sway bracing components used in automatic sprinkler systems. In cases where metric sized pipe hanger components are to be examined for Approval, test loads comparable to the United States equivalent shall be used.

1.2.2 For rigid seismic sway braces, the general requirements for seismic sway bracing components apply to the components that are attached to the structural element and the components that are attached to the sprinkler piping. Although used in testing, the component that is attached between the building-attached component and the piping-attached component is not included within the scope of the standard.

1.2.3 The evaluation of building-attached components is based on the premise that the component would either break, or deform in excess of the allowed limits, prior to either the failure of the attachment fastener, or the deflection of the structural member (e.g. beam). Therefore, the attachment fastener and structural members are not considered to be within the scope of this Approval Standard.

1.2.4 The evaluation of piping-attached components is based on the premise that the component would break, deform in excess of allowed limits, or lose its grip on the sprinkler pipe.

1.2.5 Seismic sway brace components are designed to attach to sprinkler pipe from 1 in. to 12 in. nominal pipe size.

1.2.6 In the case of rigid seismic sway brace assemblies, the general requirements and performance requirements apply to the entire assemblies.

1.2.7 Approval standards are intended to verify that the product described will meet stated conditions of performance, safety, and quality useful to the ends of property conservation.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions, and/or loss control specialists was also considered. The underlying details and assumptions that define the basis for the research and development of this Approval standard are contained in the Earthquake Spectra article *Test protocol for sprinkler-pipe seismic-brace components*, as listed in Section 1.8 of this standard.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of seismic sway bracing components and assemblies for the purpose of obtaining Approval. Seismic sway bracing components and assemblies having characteristics not anticipated by this standard may be FM Approved if performance equal, or superior, to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, seismic sway bracing components and assemblies that meet all of the requirements identified in this standard may not be FM Approved if other conditions that adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for Approval

Approval is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate

- The suitability of the product;
- The performance of the product as specified by the manufacturer and required by FM Approvals; and as far as practical,
- The durability and reliability of the product.

1.4.2 An initial facilities and procedures audit shall be conducted to evaluate the manufacturer's ability to consistently produce the product that was examined and tested as part of the Approval project. The audit shall review the facility and in-place quality control procedures used in the manufacturing of the product. Typically, areas of review are incoming inspection, work in progress, production testing, final quality control, marking, calibration of equipment, shipping procedures, and document and drawing control. These examinations are repeated periodically as part of the FM Approvals product follow-up program. (Refer to Section 5.2, Facility and Procedures Audit.)

1.5 Basis for Continued Approval

1.5.1 Continued Approval is based upon:

- Production or availability of the product as currently Approved;
- The continued use of acceptable quality assurance procedures;
- Satisfactory field experience;
- Compliance with the terms stipulated in the Approval Agreement;
- Satisfactory re-examination of production samples for continued conformity to requirements; and
- Satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' Product Follow-Up Program.

1.5.2 Also, as a condition of retaining Approval, manufacturers may not change an FM Approved product or service without prior authorization by FM Approvals. (Refer to Section 5.1.3 for further details regarding changes.)

1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this standard is **June 30, 2010** for compliance with all requirements.

1.7 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-2002, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*.

1.8 Applicable Documents

The following standards, test methods, and practices are referenced in this standard or are beneficial in understanding this standard:

American Society of Mechanical Engineers, ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/C0033-03A, www.astm.org
ASTM A153/A153M - 09, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*
ASME B36.10M-2004, *Welded and Seamless Wrought Steel Pipe*
ASTM B633-98, *Standard Specification for Electrodeposited Coatings of Zinc on Iron or Steel*
ASTM SI10 - 2002, *IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System*

FM Global, Corporate Offices, 270 Central Avenue, Johnston, RI 02919, www.fmglobal.com
P. K. Malhotra, Paul Senseny, Antonio Braga and Roger Allard, "Test protocol for sprinkler-pipe seismic-brace components," Earthquake Spectra, Volume 19, No 1, pp 87-109, February 2003.
FM Global Property Loss Prevention Data Sheets

International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org
ISO 17025 (2005), *General Requirements for the Competence of Testing and Calibration Laboratories*

Occupational Safety & Health Administration (OSHA), 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov
OSHA Code of Federal Regulations 29 CFR part 1910, *Occupational Safety and Health Standards*
OSHA Directive Number CPL1-03 titled: NRTL Program Policies, Procedures and Guidelines

1.9 Definitions

For purposes of this standard, the following terms apply:

Accepted
This term refers to installations acceptable to the authority enforcing the applicable installation rules. When the authority is FM Global, such locations are termed “FM Global Accepted.” Acceptance is based upon an overall evaluation of the installation. Factors other than the use of FM Approved equipment impact upon the decision to accept, or not to accept. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere. (Contrast with FM Approved.)

Attachment Fastener
The fastener used to connect the building-attached component to the structural member.

Connection Components
For rigid style seismic sway braces, this term refers to a rigid member, usually a length of pipe, angle iron, or strut that connects the building-attached component to the piping-attached component.

Corrosion Resistant
Having resistance to corrosion equal to or exceeding that of carbon steel coated per electro-deposit process with zinc coating thickness of a minimum of 5 µm.

FM Approvals Certification Mark
The FM Approvals Certification Marks are detailed in Appendix B. Their use is mandatory on all units of FM Approved seismic sway braces. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product.

FM Approved

This term refers to products FM Approved by FM Approvals. Such products are listed in the Approval Guide, an on-line resource of FM Approvals. All products so listed have been successfully examined by FM Approvals, and their manufacturers have signed and returned a Master Agreement to FM Approvals. These forms obligate the manufacturer to allow re-examination of the product and audit of facilities and procedures at FM Approval's discretion. It further requires the manufacturer not to deviate from the FM Approved configuration of the product without review by and agreement of FM Approvals.

Lightwall Pipe

Lightwall pipe is characterized by having a combination of outside diameter and wall thickness not suitable for cut grooving or threading. Lightwall pipe shares the same outside diameter dimensions as Schedule 40 pipe, however the wall thickness of Lightwall pipe ranges between that of Schedule 5 and 10 and can vary from manufacturer to manufacturer. The normal end connections for Lightwall pipe are: welded, roll grooved, and plain end. This pipe is also commonly referred to in industry as "Flow" pipe or "Schedule 7" pipe. There is no national or international standard for this product at this time.

Rod Stiffener

This term refers to a product that is attached directly to the all-thread hanger rod in order to provide an increased measure of resistance to buckling when subjected to axial compressive loading.

Schedule 40 Pipe

Schedule 40 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 40 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are threaded, welded, rolled or cut groove, or plain end.

Schedule 30 Pipe

Schedule 30 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 30 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are welded, rolled groove, or plain end.

Schedule 10 Pipe

Schedule 10 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 10 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are welded, rolled groove, or plain end.

Schedule 5 Pipe

Schedule 5 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 5 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are welded, roll grooved, mechanically swaged fittings.

Seismic Sway Brace – Rigid Brace Style

An assembly consisting of three components (as described below) intended to minimize the differential movement between the sprinkler system piping and the structure, to which it is attached, during an earthquake.

Building-Attached Component

A component of a seismic sway brace intended to provide a means of attachment to a structural element of a building.

Connection Component

Usually a length of pipe, angle iron, or strut that connects the building-attached component to the piping-attached component.

Piping-Attached Component

A component of a seismic sway brace intended to provide a means of attachment to the sprinkler piping.

Seismic Sway Brace – Two-Way Brace and Four-Way Brace

For risers and overhead sprinkler piping, there are two sway bracing designs; two-way and four-way. Two-way braces are designed to resist either longitudinal or lateral movement with respect to the axis of the pipe. Lateral movement is normal to longitudinal movement and is generally regarded as horizontal. Four-way sway bracing resists differential movement in all horizontal directions.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 Seismic sway bracing is used to minimize the differential movement between the sprinkler system piping and the structure to which it is attached during an earthquake. For risers and overhead sprinkler piping, there are two sway bracing designs; two-way and four-way. Two-way braces are designed to resist either longitudinal or lateral movement with respect to the axis of the pipe. Lateral movement is normal to longitudinal movement and is generally regarded as horizontal. Four-way sway bracing resists differential movement in all horizontal directions.

2.1.2 In order to meet the intent of this standard, seismic sway brace components must be examined on a model-by-model, type-by-type, manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that identical designs, fabricated in identical materials by different manufacturers or, even by different plants of the same manufacturer, have been observed to perform differently in testing. Sample seismic sway brace components, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Approval Application Requirements

2.2.1 To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to:

Hydraulics Group Manager
FM Approvals Hydraulics Laboratory
743A Reynolds Road
West Glocester, RI 02814 U.S.A.

2.2.2 The manufacturer shall provide the following preliminary information with any request for Approval consideration:

- A complete list of all models, and sizes, for the products or services being submitted for Approval consideration;
- Sprinkler piping sizes to be braced, including reference to the industry standard to which the pipe is to be manufactured, (minimum of Schedule 10 and Schedule 40) – For example, ASTM A795, Schedule 10, sizes 4, 6, 8 inch NPS;
- Connection component types and thicknesses, (i.e. pipe, strut, flats, etc.);
- General assembly drawings and one complete set of manufacturing drawings;
- Materials list(s) and material specifications (such as AISI-SAE 1020 Carbon Steel);
- Anticipated marking format;
- Specification sheets;
- Installation, operation and maintenance procedures; and;
- The number and location of manufacturing facilities.

2.3 Requirements for Samples for Examination

Following set-up and authorization of an Approval examination, the manufacturer shall submit samples for examination and testing. Sample requirements are to be determined by FM Approvals following review of the preliminary information. Sample requirements may vary depending on design features, results of prior testing, and/or the scope of the Approval examination. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototypes is at the discretion of FM Approvals. In the event that a component feature prevents the use of existing fixtures, the manufacturer shall supply a suitable test fixture to allow for the evaluation of the component.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

3.1.1 During the initial investigation and prior to physical testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The product shall be capable of being used within the limits of the Approval investigation.

3.1.2 The manufacturer's dimensional specifications and/or design drawings shall fully describe the product. All critical dimensions shall be indicated with allowed upper and lower tolerance limits clearly shown.

3.1.3 All documents pertaining to the product materials, dimensions, processing, and marking shall be controlled by the manufacturer's Quality Assurance procedures, and shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All foreign language drawings shall be provided with an English translation.

3.2 Physical or Structural Features – Rigid Brace Assemblies

3.2.1 Some of the common types of sway bracing components encompassed by this standard are:

Pipe-Attached Components	***Brace Components***	***Building-Attached Components***
Pipe Clamp U-type Clamp	Pipe Strut Structural Steel – Channel, strips	Swivel, Threaded or Non-Threaded Rigid Brace Angle Brace

3.2.2 Sprinkler Pipe-Attached Sway Brace Components

Sprinkler pipe-attached sway brace components shall be provided with a visual means to verify that the component is adequately secured to the sprinkler pipe and the bracing component. Visual verification may include, but is not limited to such means as: "flat-to-flat" relative positions of components, fasteners that bottom out when properly installed, the use of "go and no go" gauges, shearing type fasteners that shear off at the proper torque, alignment fasteners which align in a specific fashion when adjusted to the proper torque. Other methods of visual verification may be acceptable and will be examined on a case by case basis. Sprinkler pipe-attached seismic sway brace components shall have adequate strength to withstand the cyclic loading history. The component shall not break or deform more than allowed limits.

3.2.3 Sprinkler Pipe-Attached Sway Brace Components

Sprinkler pipe-attached sway brace components that are found to deform the run pipe during installation or testing are required to have a provision in the product literature that states that the installation of these components shall be far enough away from a pipe joint so that the deformation does not weaken the pipe joint.

3.2.4 Building-Attached Sway Brace Components

Building-attached components shall provide a secure connection to a building structural element and shall have adequate strength to withstand the cyclic loading history. The component shall not break or deform more than allowed limits. Building-attached components shall be provided with a visual means (See Section 3.2.2) to verify the component is adequately secured to the building structural element (if attachment is made using set-screws, etc.) and the connection component.

3.2.5 Seismic sway brace components shall be supplied with all required fasteners, pins, etc., included to make the assembly complete. The manufacturer is not required to supply the fasteners to attach building-attached components to structural members. Instructions for field installation of brace components shall also be included.

3.3 Materials

3.3.1 All materials used in these seismic sway brace components shall be suitable for the intended application. Common materials used in brace components are malleable iron, ductile iron, rolled steel, and heat treated steel. These and any other materials used in seismic sway brace components shall have physical properties necessary to render them suitable for their intended use. When unusual materials are used, special tests may be necessary to verify their suitability.

3.3.2 To provide adequate durability, any ferrous metal part shall be plated with a non-ferrous material to at least 5µm thickness as defined in ASTM B633, Service Condition SC1 (Mild), or equivalent, in order to retard oxidation of the base material. Coatings shall withstand the effects of shipping, assembly and installation, weathering and corrosion.

3.4 Markings

3.4.1 Marking on the product or, if not possible due to size, on its packaging or label, or installation instructions if accompanying the product, shall include the following information:

- Manufacturer’s name and address or marking traceable to the manufacturer;
- Model or type designation;
- Indication of strength rating, or;
- The maximum pipe size used with the component;
- FM Approval’s Certification Mark (see Appendix B).

3.4.2 Seismic sway brace components that are produced at more than one location shall be identified as the product of a particular location.

3.4.3 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as Approved. The manufacturer shall not place this model or type identification on any other product unless covered by a separate agreement.

3.4.4 The FM Approval’s Certification Mark, (see Appendix B) shall be displayed visibly and permanently on the product. The manufacturer shall not use these marks on any other product unless such product is covered by separate agreement with FM Approvals.

3.4.5 All markings shall be legible and durable.

3.5 Manufacturer's Installation Instructions

3.5.1 Installation instructions, including any special dimension requirements, shall be furnished by the manufacturer with each shipment. Installation instructions shall include the requirements for the correct installation of both building-attached and piping-attached components.

3.5.2 Where applicable, a listing of the manufacturer's recommended fasteners shall be included in order to assist in the proper selection of fasteners for building-attached components.

3.5.3 Installation instructions shall also include reference to the visual means to ensure that the proper installation of the components has been made. In the event that manual checking is the only means to verify installation, the instructions shall clearly indicate the criteria used to judge proper installation.

3.5.4 The installation instructions identified in Section 3.5.1 shall be available in multiple languages in support of regions where the product is intended to be sold.

3.6 Calibration

Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment shall be submitted to FM Approvals for its records. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or traceable to other acceptable reference standards and certified by an ISO 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service accreditation certificate as an ISO 17025, "*General Requirements for the Competence of Testing and Calibration Laboratories*", calibration laboratory is required for FM Approvals records.

The calibration of new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, and model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above. The new test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date.

3.7 Tolerances

Tolerances on units of measure shall be as described in Appendix D, unless otherwise specified.

4. PERFORMANCE REQUIREMENTS

The objective of these tests is to determine the maximum load a component can resist for 15 equal amplitude load cycles without breaking or exceeding the deformation limits. The testing of seismic sway brace components, whether building-attached, piping-attached, or sub-assemblies is comprised of a series of cyclic tests. The load rating shall be determined from the results of the cyclic tests. This standard is written based on the use of force-control test equipment. The minimum requirements for force-control have been outlined below.

The testing for piping-attached seismic sway brace components shall be performed using a 6 in. nominal length of sprinkler pipe. The testing for building-attached seismic sway brace components shall be performed using an 18 in. maximum nominal length of brace component. The load frame shall be equipped with a calibrated load-cell and a deformation-measuring device. The load frame shall be capable of imparting ± 1 in. (25 mm) deformation under cyclic conditions at 0.1 Hz frequency.

The testing for seismic sway brace assemblies shall be performed using a fixture that allows for testing using larger sections of sprinkler pipe, and the full seismic sway brace assembly. The fixture shall be mounted in such a way that the motion can be delivered to the suspended run pipe alone. The equipment used to deliver the load shall be equipped with a calibrated load cell and deformation measuring device. The equipment shall be capable of imparting ± 2 in (50 mm) deformation under cyclic conditions at 0.1 Hz frequency.

4.1 Examination

4.1.1 Requirements

The seismic sway brace components shall conform to the manufacturer's drawings and specifications and to FM Approvals requirements outlined in this Standard.

4.1.2 Test/Verification

A sample of each component shall be examined and compared to the manufacturer's drawings and shall conform to the physical, material, and marking requirements described in Section 3, General Requirements.

4.2 Cyclic Testing (Component Testing)

The purpose of this testing is to determine the load ratings for the building-attached and piping-attached subassemblies of a rigid seismic sway brace. Each of these subassemblies may consist of one or more components. Due to the influence that the pipe wall thickness has on the load rating for a given component, the testing will be performed using Schedules 10 and 40 steel pipes as standard. At the manufacturer's option, the load ratings determined with the Schedule 10 pipe may be used for Schedule 40 pipe but not vice versa.

The total allowed displacement for seismic sway brace component testing is a maximum of 1 inch (25 mm). In order to address the effect of installation angle as measured from vertical, the limiting deformation limits change as shown in the table below:

Table 4.2 Limiting Deformation along the Brace for Different Brace Orientations

Installation Angle, Θ	***Limiting Deformation***
30°	0.50 inch (12 mm)
45°	0.71 inch (18 mm)
60°	0.87 inch (22 mm)
90°	1.00 inch (25 mm)

4.2.1 Requirements

The objective of these tests is to determine the maximum load a component can resist for 15 equal amplitude cycles.

4.2.2 Test/Verification

4.2.2.1 Install the building/pipe-attach subassembly in the test fixture and subject it to the following cyclic loading profile until either the sample breaks or exceeds the deformation limit shown in Table 4.2. Record the load history and maximum deformation while under test. The frequency shall be 0.1 Hz for the duration of the test.

4.2.2.2 For pipe bracing components with expected ratings in excess of 1000 pounds (454 kg), the initial loading on the sample will be 1000 pounds (454 kg). For pipe bracing subassemblies with expected load ratings less than 1000 pounds (454 kg), the initial loading on the sample will be 250 pounds (113 kg).

4.2.2.3 With the component installed in the test fixture, and the initial load determined, subject the sample to 15 cycles alternating in direction to cause tension and compression within the sample as shown below. After the initial 15 cycles, the loading will then change to an increasing increment based on the following equation.

$$Force = X \text{ for } N \leq 15 \text{ cycles}$$

$$Force = X \times \left(\frac{15}{14}\right)^{\frac{(n-15)}{2}} \; lb \quad for \quad n > 15$$

X = 1000 for Subassemblies with ratings expected to be greater than 1000 pounds (454 kg)
X = 250 for Subassemblies with ratings expected to be less than 1000 pounds (454 kg)

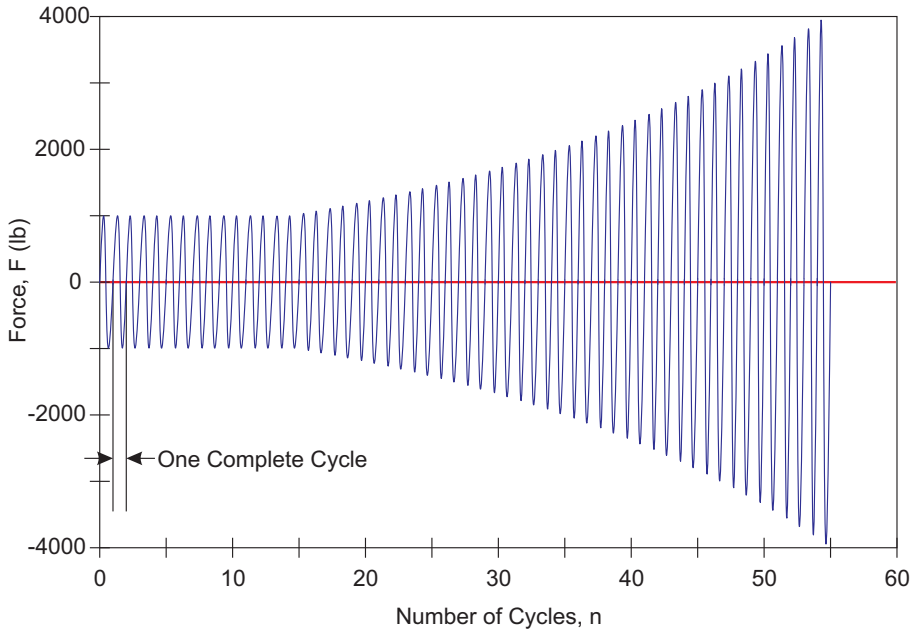


Figure 4.2 Force History Plot (Component Testing)

4.2.2.4 Once the sample has been observed to either break, or the deformation limit has been exceeded, the test is complete. Replace the sample with a new sample and repeat the cyclic test twice more, for a total of three tests.

4.2.2.5 The load rating is then found from examining the data and identifying the lowest magnitude force reading from the three samples at the point where the sample was observed to fail, or the deformation limit was exceeded. From this point, back up on the load history to the previous complete cycle and record that value.

4.3 Cyclic Tests (Assembly Testing)

The purpose of this testing is to determine the load ratings of a complete seismic sway brace assembly. This testing method may be used for rigid style seismic sway brace assemblies the resultant load rating will be assigned for the entire assembly. The entire assembly for this style testing is defined as using components of each of the categories shown in the table in Section 3.2.1.

Due to the influence that the pipe wall thickness has on the load rating for a given component, the testing will be performed using Schedules 10 and 40 steel pipes as standard. At the manufacturer's option, the load ratings determined with the Schedule 10 pipe may be used for Schedule 40 pipe but not vice versa.

The total allowed displacement for seismic sway brace assembly testing is a maximum of 2 inch (50 mm) in order to account for the allowed deformations of both the building-attached, and piping-attached components. This testing is for an entire assembly, tested as installed within the fixture at each of the installation angles individually, therefore incorporating effect of installation angle as measured from vertical. This way, the limiting deformation is always in the horizontal plane and thus has been shown in the table below as 2 inches (50 mm).

Table 4.3 Limiting Horizontal Deformation for Different Brace Orientations

Installation Angle, Θ	***Limiting Deformation***
30°	2.00 inch (50 mm)
45°	2.00 inch (50 mm)
60°	2.00 inch (50 mm)
90°	2.00 inch (50 mm)

4.3.1 Requirement

The objective of this test is to determine the load that the assembly can withstand for 15 equal amplitude load cycles. Fasteners used to install building-attached components are not included in this rating.

4.3.2 Test/Verification

4.3.2.1 Install the brace assembly in the test fixture (See Figure 4.3.2), and subject it to the following cyclic loading profile until either the sample breaks or exceeds the deformation limits shown in Table 4.3. Record the load history and maximum deformation while under test. The frequency shall be 0.1 Hz for the duration of the test.

4.3.2.2 For pipe bracing assemblies expected to exceed 2000 pounds (910 kg), the initial loading on the sample (consisting of two assemblies) will be 2000 pounds (910 kg). For pipe bracing assemblies not expected to exceed 2000 pounds (910 kg), the initial loading on the sample (consisting of two assemblies) will be 500 pounds (225 kg).

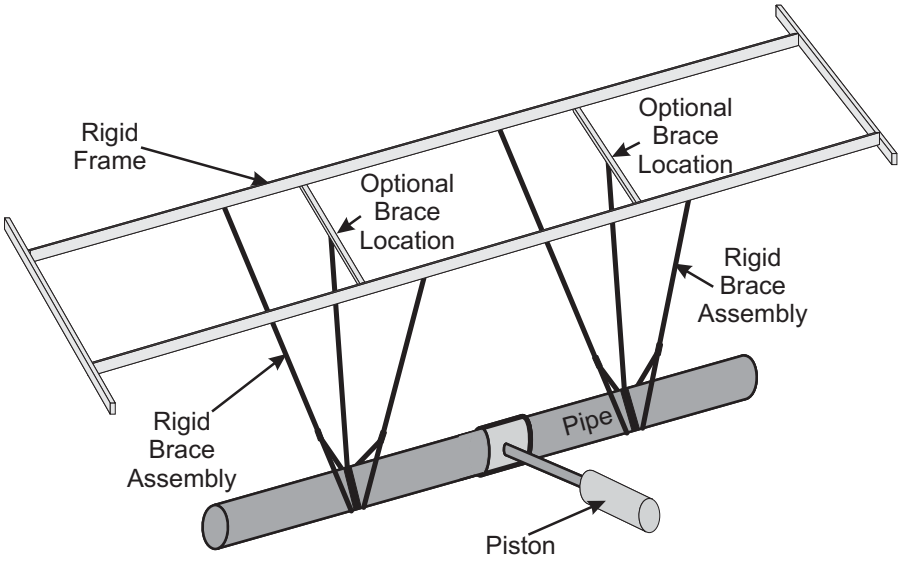


Figure 4.3.2 Test Arrangement for Assembly Testing

4.3.2.3 With the two complete brace assemblies installed in the test fixture, subject the sample to 15 cycles alternating in direction to cause tension and compression within the sample as shown below. After the initial 15 cycles, the loading will then change to an increasing increment based on the following equation.

$$Force = X \text{ for } N \le 15 \text{ cycles}$$

$$Force = X \times \left(\frac{15}{14}\right)^{\frac{(n-15)}{2}} \quad lb \quad for \quad n > 15$$

X = 2000 for assemblies with expected ratings greater than 2000 pounds (910 kg)
X = 500 for assemblies with expected ratings less than 2000 pounds (910 kg)

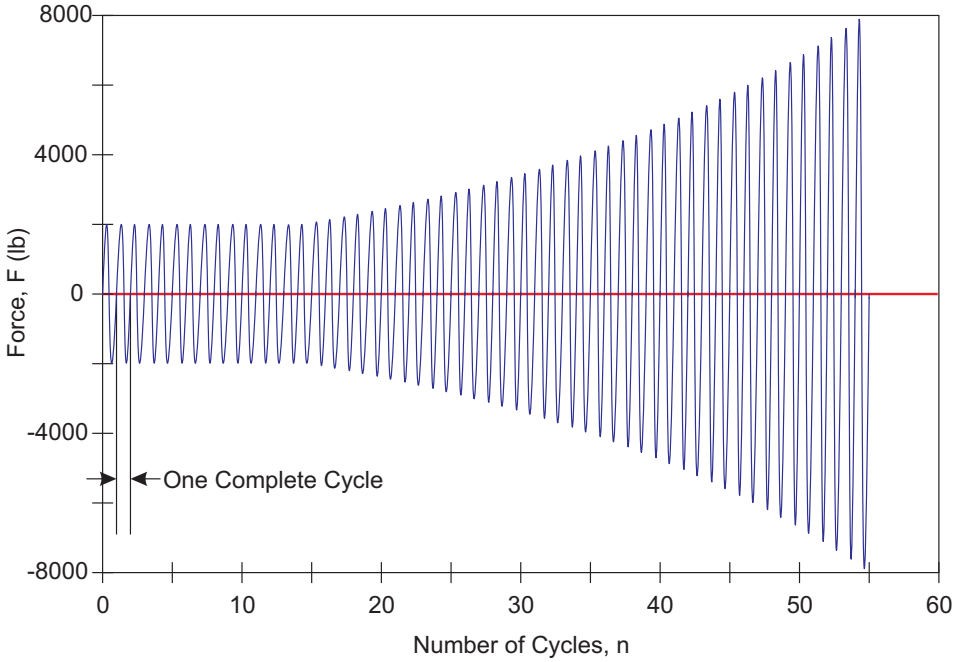


Figure 4.3.2.3 Force History Plot (Assembly Testing)

4.3.2.4 Once the sample has been observed to either break, or the deformation limit has been exceeded, the test is complete. Replace the sample with a new sample and repeat the cyclic test twice more, for a total of three tests.

4.3.2.5 The load rating is then found from examining the data and identifying the lowest magnitude force reading from the three samples at the point where the sample was observed to fail, or the deformation limit was exceeded. From this point, back up on the load history to the previous complete cycle and record that value. Since the testing for rigid sway brace assemblies requires the use of four assemblies within the fixture, the value would be divided by four for a single brace assembly.

4.4 Test Procedure

Seismic sway brace component testing may be performed by an outside laboratory, or at the manufacturer's facility at the discretion of FM Approvals. FM Approvals shall specify the range of tests to be conducted, witness the testing and obtain the data, and collect copies of the calibration certificates. In the event that testing is performed at an outside laboratory, testing may be combined with other manufacturer's products. Therefore, if a manufacturer requests to witness testing, additional time may be required.

4.5 Additional Tests

Additional tests may be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the seismic sway brace components, at the discretion of FM Approvals.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the discretion of FM Approvals and with adequate technical justification of the conditions and reasons for failure.

5. OPERATIONS REQUIREMENTS

A quality control program is required to assure that subsequent seismic sway brace components produced by the manufacturer at an authorized location shall present the same quality and reliability as the specific seismic sway brace components examined. Design quality, conformance to design, and performance are the areas of primary concern. Design quality is determined during the Approval examination and tests, and is covered in the Approval Report. Conformance to design is verified by control of quality and is covered in the Facilities and Procedures Audit (F&PA). Quality of performance is determined by field performances and by periodic re-examination and testing.

5.1 Demonstrated Quality Control Program

5.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- Existence of corporate quality assurance guidelines;
- Incoming quality assurance, including testing;
- In-process quality assurance, including testing;
- Final inspection and tests;
- Equipment calibration;
- Drawing and change control;
- Packaging and shipping; and,
- Handling and disposition of non-conformance materials.

In order to assure adequate traceability of materials and products, the manufacturer shall maintain records of all quality control tests performed for a minimum period of two years from the date of manufacture.

5.1.2 Documentation/Manual

There should be an authoritative collection of procedures and policies. Such documentation shall provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

5.1.3 Drawing and Change Control

The manufacturer shall establish a system of product configuration control that shall not allow unauthorized changes to the product. Revisions to critical documents, identified in the Approval Report, must be reported to, and authorized by, FM Approvals prior to implementation for production. The manufacturer shall assign an appropriate person or group to be responsible for reporting proposed revisions to FM Approved products to FM Approvals before implementation. In situations involving significant modifications to an FM Approved product, the notification shall be in the form of a formal request for an Approval examination. For modifications of a more common nature, the manufacturer shall provide notification to FM Approvals by means of FM Approvals Form 797, Approved Product/Specification Tested Revision Report or Address/Main Contact Change Report. Records of all revisions to all FM Approved products shall be maintained.

5.1.3.1 The table below has been included as a guide to manufacturers of what is considered to be a significant change to FM Approvals. As mentioned above, modifications that fit this category should be documented by means of a letter stating the change, and requesting a quotation for an Approval examination.

Modification	***Description/Example***
Increase of Load Rating	The product was originally Approved for a load rating of 300 lbs (136 kg), and now to be evaluated to a rating of 500 lb (227 kg).
Addition of Product Sizes	The product offering was originally Approved for 1 - 4 in. NPS, and now Approval of 6 - 8 in. NPS is desired.
Addition or Relocation of the Manufacturing Location	The product was originally Approved in location A, and now is desired to be made in locations A and B, or only in location B.
Major Changes to Critical Dimensions	Modifications to the material thickness of the attachment hardware that would result in changes in load carrying ability

5.1.3.2 The listing below has been included as a guide to manufacturers of modifications that are commonly submitted to FM Approvals on Form 797.

Modification	***Description/Example***
Change in Company Contact Information:	Name, Title, Phone Number, Fax Number, Email Address, Company office Address, Company Name
Updating of Drawings	The Form 797 is used to notify FM Approvals in the event of: minor dimensional changes to non-critical features, minor changes in notes, location of title block, re-creation of the same drawings on CAD, etc.
Changes in Markings	Please describe what changes are to be made and include a drawing of the proposed marking.
Changes in Materials	Where a new material is either superior, or comparable to material used in original Approval
Updating of Documentation	Creation of new or revisions to sales literature, installation instructions, quality manual, etc

5.1.3.3 For the instances where the modification is difficult to categorize, manufacturers are encouraged to contact FM Approvals to discuss the nature of the change, and inquire about how to send the information to FM Approvals. The examples shown in Sections 5.1.3.1 and 5.1.3.2 are based on common examples of modifications as they relate to the manufacturers of products tested to this standard.

5.2 Facilities and Procedures Audit (F&PA)

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality control program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a consistently uniform and reliable product. Initial inspections of facilities already producing similar products may be waived at the discretion of FM Approvals.

5.2.2 These audits shall be conducted periodically but at least annually by FM Approvals or its representatives or more frequently depending on jurisdictional requirements. At issue of this standard the Occupational and Safety Health Administration (OSHA) of the United States Department of Labor (OSHA Code of Federal Regulations 29 CFR part 1910, *Occupational Safety and Health Standards* and OSHA Directive Number CPL1-03 titled: NRTL Program Policies, Procedures and Guidelines) requires audits of manufacturing sites producing products for use in hazardous locations during each quarter the products is manufactured.

5.2.3 The client shall manufacture the product or service only at the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the FM Approval's Certification Mark, (see Appendix B) is not permitted at any other location without prior written authorization by FM Approvals.

5.2.4 In the event that all or part of the quality inspection is subcontracted, the manufacturer shall provide FM Approvals with documentation outlining the nature of the inspection, frequency, test details, and the pass/fail criteria that was provided to the subcontracted company, and documentation that they have received and implemented these procedures.

5.3 Manufacturer's Responsibilities

The manufacturer shall notify FM Approvals of changes in product construction, design, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation of such changes.

5.4 Manufacturing and Production Tests

5.4.1 Test Requirement No. 1 - *Dimensional Check*

The manufacturer shall measure and record critical component dimensions, material thickness, markings, and threaded connections (as applicable) at the beginning of each production run. Thereafter, these measurements shall be recorded every 4 hours. The number of samples to be measured shall be based on manufacturer's Quality Control Manual, but in no case shall be less than five samples. Measurements shall be compared to the latest revision of the component drawings.

5.4.2 Test Requirement No.2 – *Monotonic Production Test*

The manufacturer shall perform and record results from monotonic tension and compression testing at the beginning of each production run. The installation angle shall be determined by the manufacturer. Values for load, deformation, and mode of failure shall be measured using calibrated equipment and recorded. All tests shall be conducted using the manufacturer's test instructions. The number of samples shall be per the manufacturer's Quality Manual, but in no case shall be less than 5 samples in the tensile and compression loading direction. Manufacturer's test instruction shall clearly identify the pass / fail criteria.

Other methods of production testing will be evaluated by FM Approvals on a case by case basis.

APPENDIX A: Units of Measurement

Force: lb_f - “pounds force”; (N - “Newtons”)
$lb_f = N \times 4.4482$

Length: in. - “inches”; (mm - “millimeters”)
mm = in. x 25.4

ft - “feet”; (m - “meters”)
m = ft x 0.3048

Mass: lb - “pounds”; (kg - “kilograms”)
lb = kg x 0.4536

Speed: in./min - “inch per minute”; (mm/min - “millimeters per minute”)
mm/min = in./min x 25.4

Torque: $ft \cdot lb_f$ - ‘‘foot pound-force’’; (N·m - ‘‘Newton-meters’’)
$N \cdot m = 0.7376\ ft \cdot lb_f$
$kg_f \cdot m = 7.233\ lb_f \cdot ft$

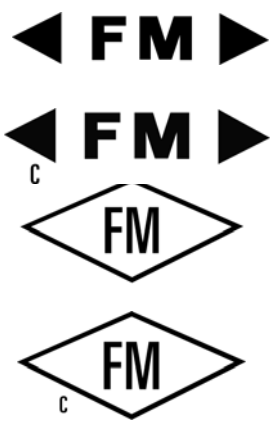
APPENDIX B: FM Approvals Certification Marks

FM Approvals certifications marks are to be used only in conjunction with products or services that have been FM Approved by FM Approvals and in adherence with usage guidelines.

FM APPROVED mark:
Authorized by FM Approvals as a certification mark for any product that has been FM Approved. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.

FM APPROVED mark with "C" only:
Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.

FM APPROVED mark with "C" and "US":
Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with US and Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



Cast-On FM APPROVALS marks:
Where reproduction of the FM APPROVED mark described above is impossible because of production restrictions, use these modified versions of the FM APPROVED mark. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable.

Downloadable art and other FM Approvals resources are available by visiting our Web site at www.fmapprovals.com

FM Approvals Certification Marks

Usage Guidelines

- All FM Approvals certification marks are the sole property of FM Approvals LLC ("FM Approvals") and are registered or the subject of applications for registration in the United States and many other countries. They are for use only according to these guidelines.
- FM Approvals certification marks may be used only on FM Approved products and related product packaging, in advertising material, catalogs and news releases. Use of FM Approvals certification marks on such material is not a substitute for use of the complete FM Approvals certification mark on FM Approved products and/or product packaging.
- No FM Approvals certification mark or aspect thereof may be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. This includes both design aspects (the FM Approvals "diamond," etc.) and word aspects ("FM," "Approved," etc.). The use of any FM Approvals certification mark as a trademark is strictly prohibited.
- The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. For example, a company may not say "ABC Company's 4100 Fire Door is FM Approved"; the proper terminology is, "ABC Company's Fire Door is FM Approved per Approval Standard 4100."
- FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.
- Products or services may not be marketed under any mark or name similar to "FM Global," "FM Approvals" or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.
- When an FM Approvals certification mark is used in advertising material or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.
- A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state, "Approval by FM Approvals pending" or "Approval by FM Approvals applied for."
- FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, "exceeds," "first" or "only" may not be used to qualify any FM Approvals certification mark.
- Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.
- The text of the FM Approvals certification marks may not be translated into any language other than English.
- FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or the manufacturer/seller/distributor of the certified products.

APPENDIX C: Sample Listing

Seismic Sway Braces:

Seismic Sway Braces are used to resist the differential movement between the sprinkler piping systems and the structure to which it is attached during an earthquake. For clarity, the individual listings below have been grouped under the sub-headings of: Seismic Sway Brace Components; and Seismic Sway Brace Assemblies. The reader is encouraged to read the sub-headings in order to be able to use the information within each section properly.

Seismic Sway Brace Components:

The listings contained within this section are based on testing that was conducted on the building-attached and piping-attached components individually. While included in the certification testing, the component used between the building-attached component and the piping-attached component was not included within the scope of Approval.

Two or more listed components may be required to form a complete seismic sway brace. The specific components required depend upon the type of building construction and the pipe size.

In all cases, the allowable capacities shown within this section have been determined by resolving the load rating (i.e., the load resulting in failure or exceedance of deformation limits) to the horizontal direction and dividing by a safety factor of 1.5 to allow the values to be used directly for Allowable Stress Design. For Load Resistance Factor Design (LRFD) capacities, the values in the table shall be multiplied by 1.5.

Company Name, Company Address

Model	*Part Description*	*Run Pipe Nominal Size*	*Run Pipe Reference*	*Allowable Horizontal Capacity (F) per Installation Angle, lb (N)*				*Remarks*
				30° - 44°	*45° - 59°*	*60° - 74°*	*75° - 90°*	
A	Loop Brace	2, 2-1/2	ASTM A53 Schd 40	1200 (5337)	1500 (6672)	1700 (7562)	2000 (8896)	a, d
A	Loop Brace	3, 4	ASTM A53 Schd 40	1500 (6672)	1600 (7117)	1800 (8006)	2100 (9341)	a, d
B	Angle Bracket		ASTM A53 Schd 40	3000 (13344)	3000 (13344)	3100 (13789)	3500 (15568)	a, b
C	Beam Attachment Assembly	3-6 in. Beam with minimum flange 1/4 in. or smaller	ASTM A53 Schd 40	2500 (11120)	2500 (11120)	2100 (9341)	1800 (8006)	a, b, c

Notes:

a. Allowable capacity of brace subassemblies have been determined by resolving the load rating (i.e., the load resulting in failure or exceedance of deformation limits) to the horizontal direction and dividing by a safety factor of 1.5 to allow the values to be used directly for Allowable Stress Design. For Load Resistance Factor Design (LRFD) capacities, the above values will need to be multiplied by 1.5.
b. Allowable capacity valid when installed with brace across beam or joist (Lateral bracing installation).
c. Allowable capacity valid when installed with brace along beam or joist (Longitudinal bracing installation).
d. Allowable capacity may be applied to ASTM A795 Schedule 10 pipe.

Seismic Sway Brace Assemblies:

The listings contained within this section are based on testing conducted on the full seismic sway brace assembly. The full seismic sway brace assembly being defined as all of the components between the building-attached component down to the piping-attached component and then back to the opposing building-attached component.

In all cases, the allowable capacities shown within this section are in the horizontal direction and have been determined by dividing the load rating (i.e., the load resulting in failure or exceedance of deformation limits) by a safety factor of 1.5 to allow the values to be used directly for Allowable Stress Design. For Load Resistance Factor Design (LRFD) capacities, the values in the table shall be multiplied by 1.5.

Company Name, Company Address

Model	*Part Description*	*Run Pipe Nominal Size*	*Run Pipe Reference*	*Allowable Horizontal Capacity (F) per Installation Angle, lb (N)*				*Remarks*
				30° - 44°	*45° - 59°*	*60° - 74°*	*75° - 90°*	
Q	Rigid Assembly	2, 2-1/2	ASTM A53 Schd 40	1200 (5337)	1500 (6672)	1700 (7562)	2000 (8896)	a, d
Q	Rigid Assembly	3, 4	ASTM A53 Schd 40	1500 (6672)	1600 (7117)	1800 (8006)	2100 (9341)	a, d
R	Rigid Assembly	3, 4	ASTM A53 Schd 40	Not Approved	3000 (13344)	3100 (13789)	Not Approved	a, b
S	Rigid Assembly	4, 5, 6, 8	ASTM A53 Schd 40	2500 (11120)	2500 (11120)	2100 (9341)	1800 (8006)	a, c

Notes:

a. Allowable capacity of brace subassemblies are in the horizontal direction and have been determined by dividing the load rating (i.e., the load resulting in failure or exceedance of deformation limits) by a safety factor of 1.5 to allow the values to be used directly for Allowable Stress Design. For Load Resistance Factor Design (LRFD) capacities, the above values will need to be multiplied by 1.5.
b. Allowable capacity valid when installed with brace across beam or joist (Lateral bracing installation).
c. Allowable capacity valid when installed with brace along beam or joist (Longitudinal bracing installation).
d. Allowable capacity may be applied to ASTM A795 Schedule 10 pipe.

APPENDIX D: Tolerances

Unless otherwise stated, the following tolerances shall apply:

Force:	± 3 lbs of value
Length:	± 2 percent of value
Temperature:	± 5 °F (+/- 3°C)
Time:	+ 5/-0 seconds + 0.1/-0 minutes + 0.1/-0 hours + 0.25/-0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68 °F ± 9 °F (20 °C ± 5 °C).

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